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# EFFECT OF FALL IRRIGATION ON CROP YIELDS AT BELLE FOURCHE, S. DAK.

By F. D. FARRELL, *Agriculturist in Charge of Demonstrations on Reclamation Projects*, and BEYER AUNE, *Farm Superintendent, Western Irrigation Agriculture.*

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## INTRODUCTION.

One of the conspicuous features of the climate of the Great Plains area is the light precipitation received during the winter months. Throughout most of the Plains region, about three-fourths of the annual precipitation occurs during the six months from April to September, inclusive,[1] so that the winter months are, comparatively, very dry. As a result, it is commonly found that after producing a crop the land remains dry from harvest time until the rainy season of the following year. The soil on such land during this period may be deficient in moisture not only near the surface but throughout the zone of action of the roots of crop plants. It has been assumed that this soil-moisture deficiency might have an unfavorable influence on the growth of crops, both by hindering the germination of spring-sown seed and by retarding or preventing the desired movement of the water received as precipitation or applied in irrigation during the growing season.

The practice of fall irrigation—the application of water to the land in the fall of the year—has been advocated as a corrective of this condition in irrigated regions. Various writers on irrigation have suggested the desirability of fall irrigation, and a few investi-

[1] Briggs, L. J., and Belz, J. O. Dry farming in relation to rainfall and evaporation. U. S. Dept. Agr., Bur. Plant Indus. Bul. 188, 71 p., 23 fig., 1 pl. 1910.

gators have made field studies of the subject. Knorr,[1] experimenting for three years on the North Platte Reclamation Project in western Nebraska with wheat, oats, barley, potatoes, sugar beets, and corn, found that the fall irrigation of the land on which these crops were to be grown increased the yield an average of 16 per cent. The yield increases secured in these experiments were ascribed to the fact that fall irrigation resulted in more moisture in the surface soil at seeding time in the spring and also in a better absorption of moisture by the soil to a depth of 6 feet during summer irrigation. These experiments were conducted on a sandy loam soil at the Scottsbluff Experiment Farm, a field station of the Bureau of Plant Industry.

The favorable results secured at Scottsbluff suggested the advisability of repeating the experiments at another point in the Great Plains area where the soil conditions are different from those at Scottsbluff. Accordingly, in the autumn of 1913 a series of fall-irrigation experiments involving oats, sugar beets, flax, potatoes, barley, corn, and wheat was inaugurated at the Belle Fourche Experiment Farm on the Belle Fourche Reclamation Project in western South Dakota. The experiments with these seven spring-planted crops were continued through 1914, 1915, and 1916. The results secured are reported in this bulletin.[2]

## RAINFALL.

During the nine years, 1908 to 1916, inclusive, the annual rainfall at the Belle Fourche Experiment Farm ranged from 6.64 inches, in 1911, to 21.02 inches, in 1915, the mean for the 9-year period being 14.05 inches. In connection with the problem of fall irrigation it is important to consider the distribution of the rainfall with reference to the fall period—the period between the beginning of harvest and the time of fall irrigation—and to the winter period. The mean rainfall of these periods during the nine years of record and the actual rainfall during the time in which the fall-irrigation experiments were conducted are shown in Table I.

TABLE I.—*Precipitation at the Belle Fourche Experiment Farm, 1908 to 1916, inclusive.*

| Period covered. | Mean, nine years, 1908 to 1916. | Period of experiment. | | | |
|---|---|---|---|---|---|
| | | 1913 | 1914 | 1915 | 1916 |
| Total annual | 14.05 | 12.53 | 11.70 | 21.02 | 13.95 |
| Fall period (August to October, inclusive) | 3.75 | 4.50 | 3.24 | 2.95 | ..... |
| Winter period (November to March, inclusive) | 2.15 | 1.84 | | 2.52 | 1.99 |

[1] Knorr, Fritz. Experiments with crops under fall irrigation at the Scottsbluff Reclamation Project Experiment Farm. U. S. Dept. Agr. Bul. 133, 17 p., 5 fig. 1914.

[2] The writers desire to acknowledge their indebtedness to Mr. O. R. Mathews, Assistant, Dry-Land Agriculture Investigations, for assistance in the conduct of these experiments.

The table shows the light precipitation which occurs during the winter months, from November to March, inclusive. During two of the three winters included in the period of experiment there was somewhat less than the mean winter rainfall for the period of record, 2.15 inches, and during the other there was slightly more than the mean. Likewise, two of the three fall periods affecting the experiments were drier and one was wetter than the mean for this fall period, 3.75 inches. From this it would appear that if fall irrigation were desirable at Belle Fourche, its benefits would have been emphasized during the period of these experiments.

## SOIL.

The soil on which these experiments were conducted is an extremely heavy clay of the class popularly known as "gumbo." Soils of this general character cover wide areas in the northern Great Plains. This particular soil has been classified by the Bureau of Soils as Pierre clay, of which the average mechanical composition is reported[1] as follows:

| | Per cent. |
|---|---|
| Fine gravel | 0.2 |
| Coarse sand | 1.1 |
| Medium sand | 1.4 |
| Fine sand | 5.5 |
| Very fine sand | 13.0 |
| Silt | 43.2 |
| Clay | 35.0 |

According to the same authority, the Pierre clay covers about one-third of the area of the Belle Fourche Reclamation Project and occurs on this area to a uniform depth of about 6 feet. It has been formed through the weathering of the underlying beds of Pierre shale. According to a report[2] of a reconnoissance soil survey made by the Bureau of Soils, the Pierre clay covers an area of nearly eight million acres in the western half of South Dakota.

Important characteristics of this soil are its great water-carrying capacity, its high water retentivity, and the extreme changes of volume which accompany changes in its moisture content. Mathews[3] found that this soil will carry about 30 per cent of water and that about half of this is available to crops. The latter do not begin to suffer from lack of water unless the soil moisture content approaches 17 per cent, which is approximately the wilting coefficient of this soil. The importance in fall irrigation of the extreme changes of volume accompanying changes in moisture content of this soil will be discussed later.

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[1] Strahorn, A. T., and Mann, C. W. Soil survey of the Belle Fourche area, South Dakota. *In* U. S. Dept. Agr., Bur. Soils, Field Oper. 1907 [9th Rpt.], p. 898. 1909.

[2] Coffey, G. N., and others. Reconnoissance soil survey of western South Dakota. *In* U. S. Dept. Agr., Bur. Soils, Field Oper. 1909 [11th Rpt.], p. 1401–1476, illus., pl. 9–15. 1912.

[3] Mathews, O. R. Water penetration in the gumbo soils of the Belle Fourche Reclamation Project. U. S. Dept. Agr. Bul. 447, 12 p., 4 fig. 1916.

## METHODS USED IN THE EXPERIMENTS.

The experiments were conducted in field P, Series I, II, III, and IV, seven tenth-acre plats being used in each series. A diagram of these plats is shown in figure 1. The land was first broken in August, 1911, and it produced oats in 1912 and again in 1913. It is uniform in topography and soil. The crops of 1912 and 1913 were harvested from the field as a whole, no record having been secured of the production of the different series of plats. Series II and IV were irrigated on November 11, 1913, November 11, 1914, and November 10, 1915. Except for this fall irrigation, the treat-

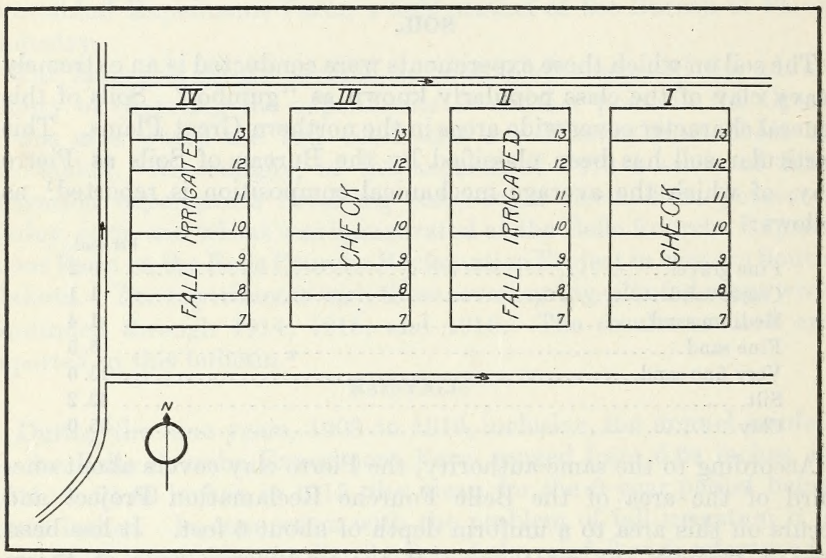


FIG. 1.—Diagram of a part of field P, Belle Fourche Experiment Farm, showing the location of the plats used in the fall-irrigation experiments. The arrows indicate the direction of the flow of the water in the irrigation laterals supplying these plats.

ments applied to Series II and IV were uniform with those applied to Series I and III.

The fall irrigation was applied each year after the plats were plowed, except that in the autumn of 1914 the plats which that year had produced intertilled crops were not plowed. Low earth dikes were thrown up at the lower side of the plats to impound the water sufficiently to insure a complete covering of the land. The water was then applied by flooding and allowed to run on each plat from three to four hours. The summer irrigation of each crop was uniform on all four series as to both time and method of application. No attempt was made to measure the water applied, but the methods of irrigation recognized in the locality as good-farming methods were followed. The sugar beets and potatoes were irrigated by the furrow method and the other crops by field flooding.

The experiments were conducted in duplicate each year, the seven plats in Series I duplicating those in Series III, while the plats in Series II and IV were duplicates. The following crop varieties were used: Oats, Great Dane in 1914 and Swedish Select in 1915 and 1916; sugar beets, South Dakota No. 40 in 1914 and Kleinwanzleben in 1915 and 1916; flax, Minnesota No. 25; potatoes, Eureka in 1914 and 1915 and U. S. No. 4452 in 1916; barley, Minnesota No. 6 in 1914, Himalaya (Guy Mayle) in 1915, and Chevalier in 1916; corn, Payne White Dent in 1914 and 1916 and Martens White Dent in 1915; and wheat, Defiance in 1914, Pringle Champlain in 1915, and Marquis in 1916. The positions occupied by the crops on each of the four series each year, the crop sequence on each plat during the 3-year period, and the number of summer irrigations applied are shown in Table II.

TABLE II.—*Sequence of crops and number of irrigations applied to each in the fall-irrigation experiments at the Belle Fourche Experiment Farm in 1914, 1915, and 1916.*

| Plat. | 1914 | | 1915 | | 1916 | |
|---|---|---|---|---|---|---|
| | Crop. | Number of irrigations. | Crop. | Number of irrigations. | Crop. | Number of irrigations. |
| No. 7 | Oats | 3 | Beets | 1 | Oats | 1 |
| No. 8 | Beets | 3 | Flax | 2 | Potatoes | 1 |
| No. 9 | Flax | 2 | Potatoes | 1 | Beets | 2 |
| No. 10 | Potatoes | 4 | Barley | 1 | Wheat | 1 |
| No. 11 | Barley | 2 | Corn | 1 | Barley | 1 |
| No. 12 | Corn | 3 | Wheat | 2 | Corn | 1 |
| No. 13 | Wheat | 2 | Oats | 2 | Flax | 1 |

As shown in Table II, an intertilled crop followed a close-planted crop on each plat except No. 13 in 1915 and 1916 and No. 10 in 1916. More irrigation was necessary in 1914 than in either 1915 or 1916, as the growing season of 1914 received somewhat less rainfall than either of the others. The variations in both crop sequence and summer irrigation were the same on all four series.

All cultural operations on the four series were uniform as to both character and time of performance throughout the period of experiment. These included the ordinary operations incident to the production of the seven field crops involved. The land was manured from October 6 to 10, 1915, when 12 tons per acre of well-rotted barnyard manure were applied uniformly to all the plats.

## RESULTS OF THE EXPERIMENTS.

In the conduct of these experiments attention was directed chiefly to the crop yields secured on fall-irrigated land as compared with those of land not so irrigated and to the soil-moisture conditions on the two groups of plats, particularly before the first summer irrigation each season. It was to be expected that any important

differences in the yields of the crops on the several plats would be associable with soil-moisture differences in the spring, as the only variation in the treatment of the land was the irrigation applied to half the plats in the fall of each year.

### CROP YIELDS.

Two plats of each of the seven crops were grown each year on the fall-irrigated land, and the same number were grown on check series, the latter receiving no fall irrigation. The yields are reported in detail in Table III.

TABLE III.— *Yields of crops in the fall-irrigation experiments at the Belle Fourche Experiment Farm in 1914, 1915, and 1916.*

| Plats and year. | Series. | Wheat. | Oats. | Barley. | Flax. | Corn. | Beets. | Potatoes. |
|---|---|---|---|---|---|---|---|---|
| Fall-irrigated plats: | | *Bushels.* | *Bushels.* | *Bushels.* | *Bushels.* | *Bushels.* | *Tons.* | *Bushels.* |
| 1914 | II | 31.5 | 47.8 | 29.1 | 17.0 | 53.4 | 8.9 | 172 |
| | IV | 28.5 | 39.0 | 26.8 | 10.5 | 45.8 | 7.3 | 127 |
| 1915 | II | 24.0 | 70.9 | 35.7 | 18.8 | 29.3 | 5.1 | 108 |
| | IV | 19.3 | 60.6 | 34.8 | 16.3 | 29.0 | 3.6 | 77 |
| 1916 | II | 15.5 | 80.6 | 39.2 | 10.4 | 50.4 | 13.2 | 267 |
| | IV | 13.8 | 72.2 | 38.3 | 9.1 | 45.4 | 12.2 | 254 |
| Average, three years | | 22.1 | 61.9 | 33.9 | 13.7 | 42.2 | 8.4 | 167 |
| Check plats: | | | | | | | | |
| 1914 | I | 24.6 | 40.0 | 28.7 | 17.4 | 47.2 | 9.5 | 173 |
| | III | 19.3 | 47.8 | 26.0 | 14.8 | 51.4 | 7.1 | 158 |
| 1915 | I | 22.7 | 80.0 | 43.2 | 16.3 | 29.3 | 5.9 | 105 |
| | III | 24.5 | 80.3 | 33.5 | 19.1 | 33.7 | 5.7 | 100 |
| 1916 | I | 14.3 | 73.9 | 41.8 | 12.1 | 47.9 | 13.5 | 225 |
| | III | 15.3 | 84.7 | 43.6 | 11.8 | 53.9 | 13.9 | 272 |
| Average, three years | | 20.1 | 67.8 | 36.1 | 15.2 | 43.9 | 9.2 | 172 |

In order to facilitate comparisons of the yields shown in Table III, the figures have been calculated in percentages, and the relative yields are shown in Table IV, in which the yields of the check plats are represented as 100 per cent. The yield shown for each crop is the average of duplicate plats.

TABLE IV.—*Relative yields (expressed in percentages) of crops in the fall-irrigation experiments at the Belle Fourche Experiment Farm in 1914, 1915, and 1916.*

| Crop. | 1914 | | | 1915 | | | 1916 | | | 3-year average. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fall irrigated. | Check. | Gain or loss by fall irrigation. | Fall irrigated. | Check. | Loss by fall irrigation. | Fall irrigated. | Check. | Gain or loss by fall irrigation. | Fall irrigated. | Check. | Gain or loss by fall irrigation. |
| Wheat | 137 | 100 | +37 | 92 | 100 | − 8 | 98 | 100 | − 2 | 110 | 100 | +10 |
| Oats | 99 | 100 | − 1 | 82 | 100 | −18 | 96 | 100 | − 4 | 91 | 100 | − 9 |
| Barley | 102 | 100 | + 2 | 92 | 100 | − 8 | 91 | 100 | − 9 | 94 | 100 | − 6 |
| Flax | 85 | 100 | −15 | 99 | 100 | − 1 | 88 | 100 | −12 | 90 | 100 | −10 |
| Corn | 101 | 100 | + 1 | 94 | 100 | − 6 | 94 | 100 | − 6 | 96 | 100 | − 4 |
| Beets | 98 | 100 | − 2 | 74 | 100 | −26 | 93 | 100 | − 7 | 91 | 100 | − 9 |
| Potatoes | 90 | 100 | −10 | 90 | 100 | −10 | 105 | 100 | + 5 | 97 | 100 | − 3 |
| All crops | 102 | 100 | + 2 | 89 | 100 | −11 | 95 | 100 | − 5 | 96 | 100 | − 4 |

The figures in Table IV show that in 1914 the yields of wheat, barley, and corn were higher on the fall-irrigated plats than on the check plats, the increases being 37, 2, and 1 per cent, respectively, while the yields of the four other crops were lower on the fall-irrigated land, and that the average yield increase of the seven crops in that year was 2 per cent in favor of fall irrigation. In 1915 the yields of all the crops were lower on the fall-irrigated land, the average decrease being 11 per cent. In 1916 all the crops yielded less on the fall-irrigated plats than on the checks, except potatoes, which yielded 5 per cent more. In the 3-year average, wheat on fall-irrigated land showed an increase of 10 per cent, while all the other crops showed decreases ranging from 3 to 10 per cent, the average yield decrease of the seven crops on fall-irrigated land for the 3-year period being 4 per cent of the average yield of the check plats.

The fact that of the 42 duplicate plat averages secured in the 3-year period only four were in favor of fall irrigation would support a presumption that fall irrigation on this soil was detrimental. However, since not all the yields were against fall irrigation, it is possible that the yield variations were accidental. In order to determine whether these differences were significant, the probable errors of the average yields have been calculated. The results are shown in Table V, in which the yields secured during the 3-year period are summarized.

TABLE V.—*Summary of the yields secured in the fall-irrigation experiments at the Belle Fourche Experiment Farm in 1914, 1915, and 1916, showing the probable errors of the averages.*

| Crop. | Unit of yield. | Fall-irrigated plats. | | Check plats. | | Difference in favor of fall irrigation. |
|---|---|---|---|---|---|---|
| | | Number of plats averaged. | Average yield per acre. | Number of plats averaged. | Average yield per acre. | |
| Wheat | Bushels | 6 | 22.1± 2.2 | 6 | 20.1± 1.4 | +2.0± 2.6 |
| Oats | do | 6 | 61.9± 5.0 | 6 | 67.8± 6.0 | −5.9± 7.8 |
| Barley | do | 6 | 33.9± 1.5 | 6 | 36.1± 2.5 | −2.2± 2.9 |
| Flax | do | 6 | 13.7± 1.4 | 6 | 15.2± .9 | −1.5± 1.7 |
| Corn | do | 6 | 42.2± 3.3 | 6 | 43.9± 3.1 | −1.7± 4.5 |
| Beets | Tons | 6 | 8.4± 1.1 | 6 | 9.2± 1.1 | − .8± 1.5 |
| Potatoes | Bushels | 6 | 167 ±23.0 | 6 | 172 ±19.0 | −5.0±30.0 |

The figures in the last column in Table V show for each of the seven crops the difference between the average yield of the fall-irrigated plats and that of the check plats during the 3-year period. None of the differences was as great as the probable error, so that all must be regarded as insignificant. A similar tabulation of the yields of straw and stover (which are not shown here) produces a like result, there being no significant differences in the average yields of these products.

The explanation of the somewhat lower average yields secured on the fall-irrigated land lies in the relatively low productivity of Series

IV, one of the two fall-irrigated series. The 3-year average yield of the crops on Series IV was 16 per cent lower than the corresponding average of Series II, while the 3-year averages of the two check series, I and III, were identical. The relatively low productivity of Series IV may have been associated with a heavy infestation of gumbo weed (*Iva axillaris*). This weed was more abundant on Series IV than on any of the other series throughout the period of experiment. At any rate, there is nothing in the data to indicate that fall irrigation influenced the crop yields.

### SOIL MOISTURE.

When the experiments were planned, it was the intention to make soil-moisture determinations shortly after the fall irrigation each year and also during the early part of the growing season. It was found, however, that because of cold weather the soil remained wet so long after the fall irrigation that fall sampling was impracticable. All the soil-moisture data available, therefore, were secured during the spring and early summer of each of the three years of the period of the experiment. In each sampling two cores were taken on each plat and composited to a single sample for each foot section.

*Soil moisture in 1914.*—Three samplings were made in 1914, on May 5, June 18, and June 27. The samples secured on May 5 were taken from the plats seeded to oats, barley, and wheat, two plats of each crop on the fall-irrigated land and the same number of check plats, a total of six plats representing each fall treatment. These samples were taken 34 days before the first irrigation. The second set of samples, taken June 18, was from the same plats as the May 5 samples and from the two flax plats, a total of eight plats representing each fall treatment. This sampling was done 10 days after the first irrigation of the oats, wheat, and barley and one day after the flax was irrigated. The samples secured on June 27 were from the same plats as those taken on June 18, and no irrigation water was applied between the two sampling dates. These moisture determinations were made to a depth of 4 feet. A summary of the results is given in Table VI, which also shows the probable errors of the averages of moisture content.

Table VI shows that on May 5 the average moisture content of the upper 3 feet of soil on the fall-irrigated plats was higher than that of the corresponding depths on the check plats, the greatest difference being in the second foot, where it amounted to $8.3 \pm 0.5$ per cent. The soil of all the plats, however, contained an abundance of moisture, the moisture content being well above the wilting coefficient, which is approximately 17 per cent. The difference in the moisture content of the fourth foot on the same date, $2.2 \pm 1.2$ per cent, was insignificant. On June 18, after the plats had been irrigated, the only significant differences were found in the second and third feet, where the soil of the fall-irrigated plats contained about 5 per cent more

moisture than that of the check plats. On June 27 there were no significant differences in moisture content, all differences being less than their probable errors. It will be noted that the moisture content of the fourth foot was practically the same on each of the three sampling dates. The results of the moisture determinations made in 1914 showed that while the soil of the fall-irrigated plats contained more moisture than that of the check plats early in the season, when all the plats had abundant moisture, the differences decreased as the season advanced and disappeared before the end of June.

TABLE VI.—*Summary of the results of soil-moisture determinations made in 1914 in the fall-irrigation experiments at the Belle Fourche Experiment Farm.*

| Date. | Depth. | Fall-irrigated plats. | | Check plats. | | Difference in favor of fall irrigation. |
|---|---|---|---|---|---|---|
| | | Number of plats averaged. | Moisture content. | Number of plats averaged. | Moisture content. | |
| | *Feet.* | | *Per cent.* | | *Per cent.* | *Per cent.* |
| May 5 | 1 | 6 | 28.7±0.4 | 6 | 25.1±0.6 | +3.6±0.7 |
| Do | 2 | 6 | 28.8± .4 | 6 | 20.5± .3 | +8.3± .5 |
| Do | 3 | 6 | 26.6± .3 | 6 | 21.0± .3 | +5.6± .4 |
| Do | 4 | 6 | 21.7±1.0 | 6 | 19.5± .7 | +2.2±1.2 |
| June 18 | 1 | 8 | 23.1± .6 | 8 | 21.5± .7 | +1.6± .9 |
| Do | 2 | 8 | 25.3± .7 | 8 | 20.3± .9 | +5.0±1.1 |
| Do | 3 | 8 | 26.5± .6 | 8 | 20.9± .5 | +5.6± .8 |
| Do | 4 | 8 | 21.5± .8 | 8 | 20.2± .9 | +1.3±1.2 |
| June 27 | 1 | 8 | 22.3± .6 | 8 | 22.1± .7 | + .2± .9 |
| Do | 2 | 8 | 25.8± .4 | 8 | 25.0± .7 | + .8± .8 |
| Do | 3 | 8 | 26.4± .6 | 8 | 26.3± .9 | + .1±1.1 |
| Do | 4 | 8 | 20.8± .8 | 8 | 20.7± .9 | + .1±1.2 |

*Soil moisture in 1915.*—The sampling in 1915 was done on May 24 and June 10. All the plats in Series I and II were sampled on the first date and those in Series III and IV on the second. No irrigation water was applied to any of the plats in 1915 until July 14, so that the moisture determinations were made five and seven weeks, respectively, before the first irrigation. The samples were taken to a depth of 3 feet. Table VII gives a summary of the results of the moisture determinations, together with the probable errors of the averages of moisture content.

TABLE VII.—*Summary of the results of soil-moisture determinations made in 1915 in the fall-irrigation experiments at the Belle Fourche Experiment Farm.*

| Date. | Depth. | Fall-irrigated plats. | | Check plats. | | Difference in favor of fall irrigation. |
|---|---|---|---|---|---|---|
| | | Number of plats averaged. | Moisture content. | Number of plats averaged. | Moisture content. | |
| | *Feet.* | | *Per cent.* | | *Per cent.* | *Per cent.* |
| May 24 | 1 | 7 | 29.2±0.3 | 7 | 30.4±0.2 | −1.2±0.3 |
| Do | 2 | 7 | 29.4± .4 | 7 | 29.4± .4 | 0 |
| Do | 3 | 7 | 28.1± .2 | 7 | 26.0± .9 | +2.1± .9 |
| June 10 | 1 | 7 | 30.0± .3 | 7 | 30.3± .6 | − .3± .7 |
| Do | 2 | 7 | 29.8± .2 | 7 | 29.4± .6 | + .4± .6 |
| Do | 3 | 7 | 27.9± .3 | 7 | 27.6± .7 | + .3± .8 |

Except for a very slightly lower average moisture content in the first foot of the fall-irrigated plats sampled May 24, the moisture determinations made in 1915 disclosed no differences large enough to be considered significant between the fall-irrigated plats and the checks. As in the spring of 1914, the soil on all the plats sampled contained an abundant supply of moisture. As the moisture content of all the plats before the first irrigation was found to be substantially the same, no further moisture determinations were made during the season.

*Soil moisture in 1916.*—The first irrigation in 1916 was applied July 6. Soil-moisture determinations were made to a depth of 2 feet on all the plats in oats, wheat, and barley on June 10, and the plats in potatoes, beets, corn, and flax were sampled to the same depth on June 30. The results of the two samplings are summarized in Table VIII, which also shows the probable errors of the averages of moisture content.

TABLE VIII.—*Summary of the results of soil-moisture determinations made in 1916 in the fall-irrigation experiments at the Belle Fourche Experiment Farm.*

| Date. | Depth. | Fall-irrigated plats. | | Check plats. | | Difference in favor of fall irrigation. |
|---|---|---|---|---|---|---|
| | | Number of plats averaged. | Moisture content. | Number of plats averaged. | Moisture content. | |
| | *Feet.* | | *Per cent.* | | *Per cent.* | *Per cent.* |
| June 10 | 1 | 6 | 27.7±0.6 | 6 | 27.4±1.0 | +0.3±1.2 |
| Do | 2 | 6 | 29.2± .8 | 6 | 29.2± .9 | 0 ±1.2 |
| June 30 | 1 | 8 | 29.7± .6 | 8 | 29.9±1.2 | − .2±1.3 |
| Do | 2 | 8 | 30.2± .3 | 8 | 30.1± .4 | + .1± .5 |

The results of the soil-moisture determinations made in 1916 were practically the same as those secured in 1915. The soil on all the plats contained an abundance of moisture at the time of sampling, and there was no significant difference between the moisture content of the fall-irrigated plats and that of the checks.

The results of the determinations made during the three years may be summarized by the statement that any higher soil-moisture content resulting from fall irrigation was found only at times when the soil on both the fall-irrigated plats and the check plats was well supplied with water and that all significant differences in soil moisture disappeared early in the growing season, so that the crops showed no effects of fall irrigation.

## CHARACTER OF SOIL THE DETERMINING FACTOR.

The fact that fall irrigation produced no effect on crop yields at Belle Fourche while it resulted in decidedly higher yields at Scottsbluff makes it desirable to compare the rainfall and the soil conditions at the two places. The comparison is shown in Table IX.

TABLE IX.—*Rainfall and soil conditions of the Scottsbluff and Belle Fourche Experiment Farms.*

| Items of comparison. | Scottsbluff. | Belle Fourche. |
|---|---|---|
| Mean precipitation (inches): | | |
| Annual | 14.47 | 14.05 |
| Fall period (August to October, inclusive) | 4.96 | 3.75 |
| Winter period (November to March, inclusive) | 1.35 | 2.15 |
| Total (August to March, inclusive) | 6.31 | 5.90 |
| Soil: | | |
| Type | Sandy loam. | Pierre clay. |
| Field moisture-carrying capacity ..... per cent [1] | 13 | 27 |
| Wilting coefficient ..... do [1] | 6 | 17 |

[1] These figures, which represent average conditions at the two field stations, were obtained from the Office of Dry-Land Agriculture.

It will be noted that the precipitation at Scottsbluff does not differ materially from that at Belle Fourche, either as to the total quantity or as to the quantities received during the fall and winter periods. The soils represent the essential difference between the two places in relation to fall irrigation. The figures showing moisture-carrying capacity and wilting coefficient indicate something of the wide dissimilarity of the two types of soil. The sandy loam, being coarse grained, has a low moisture-carrying capacity and a low wilting coefficient. On the other hand, the extremely fine-grained Pierre clay has more than double the moisture-carrying capacity of the sandy loam and its wilting coefficient is nearly three times as high.

The soil at Scottsbluff is readily pervious to water to a depth of at least 6 feet, and its permeability is higher when the soil is moist than when it is dry. Knorr [1] found with this soil that water applied during the regular irrigation season percolated deeper on the plats on which the moisture content was relatively high as a result of fall irrigation than on the check plats where the soil moisture content was comparatively low. This fact, together with the greater quantity of moisture available in the fall-irrigated plats at planting time, is believed to explain the beneficial effects of fall irrigation at Scottsbluff.

The moisture relationships of the soil at Belle Fourche are very different from those at Scottsbluff. At Belle Fourche the soil is practically impervious except when it is dry, and the depth of water percolation depends chiefly upon the extent to which the soil is cracked as a result of dryness. The addition of moisture causes the soil to expand rapidly, and as expansion increases permeability decreases. After making an extensive study of water penetration in these soils, Mathews [2] states that "On a dry soil, penetration takes place rapidly to a depth of about 2 feet because of the cracked con-

[1] Knorr, Fritz. Experiments with crops under fall irrigation at the Scottsbluff Reclamation Project Experiment Farm. U. S. Dept. Agr. Bul. 133, 17 p., 5 fig. 1914.

[2] Mathews, O. R. Water penetration in the gumbo soils of the Belle Fourche Reclamation Project. U. S. Dept. Agr. Bul. 447, p. 11. 1916.

dition of the soil near the surface. After the layer of easily penetrated soil becomes wet, it becomes so swollen and compact that it is nearly impervious, and further water movement is very slow."

The results secured in the fall-irrigation experiments at Belle Fourche are in accord with these observations. The application of irrigation water in the autumn filled the surface soil to its moisture-carrying capacity, but apparently had no effect beyond the third foot. Irrigation water applied uniformly to all plats during the growing season, together with the natural precipitation, equalized the moisture content of the soil in these plats, irrespective of their treatment the previous fall. It is important to note also that an abundance of moisture was present in all the plats at the time of sampling in the spring and early summer and that after this time moisture was supplied by irrigation.

These facts account for the absence of significant differences between the average yields of crops on the fall-irrigated plats and those secured on the check plats. It is possible that if an adequate supply of moisture had not been maintained by irrigation during the growing season the soil-moisture content of the fall-irrigated land would have been higher in the spring than that of the check plats. It seems certain, however, that where crops are properly irrigated during the growing season fall irrigation on this soil will have no material effect.

## SUMMARY.

The light precipitation received during the winter months in the Great Plains area commonly causes soil to remain dry from the time crops are harvested until the rainy season the following year. In some soils this deficiency of moisture may have an unfavorable influence on the growth of crops, both by hindering the germination of spring-sown seed and by retarding or preventing the desired movement of the water received as precipitation or applied in irrigation during the growing season.

Fall irrigation has been advocated as a corrective of this condition in irrigated regions. It has been found efficacious on sandy loam soil in western Nebraska, where it resulted in increased soil moisture in the spring and in greater moisture absorption by the soil throughout the irrigation season.

In order to test the practice of fall irrigation on a heavy clay soil, experiments were conducted at the Belle Fourche Experiment Farm, in western South Dakota, in 1914, 1915, and 1916. These experiments included wheat, oats, barley, flax, potatoes, sugar beets, and corn, each crop being grown each year in duplicate tenth-acre plats both on fall-irrigated land and on land which received no fall irrigation.

There were no significant differences between the average yields secured on the fall-irrigated plats and those on the check plats.

Soil-moisture determinations were made in the spring and early summer each year. In 1914 they disclosed no significant differences in the moisture content of the soil resulting from fall irrigation except that in the first two of the three samplings more moisture was found in the first 3 feet of the fall-irrigated plats than in the corresponding depths of the check plats. No effect was noted beyond the third foot. The difference found in the upper 3 feet existed at a time when all the plats contained abundant moisture, and it disappeared before the end of June. No significant differences were found in 1915 or 1916.

The failure of fall irrigation to increase crop yields in these experiments seems to be attributable to the character of the soil at Belle Fourche. This soil is a heavy clay, which will absorb water only when dry and which expands rapidly when moisture is added to it. This expansion so compacts the soil as to make it impervious, so that the storage of water in the lower depths for the use of crops is not practicable.

## PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE ON RELATED SUBJECTS.

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Experiments With Crops Under Fall Irrigation at the Scottsbluff Reclamation Project Experiment Farm. (Department Bulletin 133.)

Sugar-beet Growing Under Irrigation. (Farmers' Bulletin 567.)

Irrigated Pastures for Northern Reclamation Projects. (Bureau of Plant Industry, D. R. P.–2.)

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